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SPECIFICATION

A Corrosion-Resistant Metal Made Sensor for Fluid
and
A Fluid Supply Device for which The Sensor Is Employed

Field of the Invention

[0001] The present invention is employed mainly for detecting a mass flow rate and/or pressure in a gas supply line and the like with semiconductor manufacturing facilities, and is concerned with a corrosion-resistant metal made sensor for fluid and a fluid supply device for which the sensor is employed, of which all the gas contacting faces are formed of corrosion-resistant metals such as stainless steel (SUS316L) and the like having excellent corrosion resistance even to highly corrosive fluids, thus enabling to achieve to make it particle-free and leak-free and further to enhance the detecting accuracy.

Background of the Invention

[0002] Conventionally, a capillary thermal type mass flow rate sensor or a silicon-made ultra-small sized thermal type mass flow rate sensor, for which micro-machine technologies have been employed, has been widely used to measure a mass flow rate of fluid in the technical fields such as the chemical analysis equipment and the like.

The former, or the capillary thermal type mass flow rate sensor is characterized by that the sensor allows its gas contacting faces of the sensor to

be made of stainless steel because of its structure, thus enabling to enhance its corrosion resistance to fluids to be measure at ease.

[0003] However, the capillary thermal type mass flow sensor is required to be equipped with a resistance wire for a heater to be wound to heat a capillary tube, thus causing a problem that might lead to unevenness in property among he products.

Another problem may be that the response speed of a mass flow rate sensor becomes slow due to the relatively large heat capacities of the

capillary tube and the resistance wire for a heater.

[0004] On the other hand, along with the development in so-called micro-machine technologies in recent years, the development and utilization of the latter, or a silicon-made ultra-small sized thermal type mass flow rate sensor have been widely under way. It has become popular not only in the chemical-related fields but also in the industrial manufacturing fields such as an automobile industry and the like due to the reason that a silicon-made ultra-small sized thermal type mass flow rate sensor can be manufactured under a single processing, thus reducing unevenness in properties among the products, and achieving the extremely fast response speed as a sensor by making heat capacities small by downsizing, all of which are regarded as excellent characteristics of the sensor.

[0005] However, it is noted that there exist many problems to be solved with said silicon-made ultra-small sized thermal type mass flow rate sensor. Among other things, corrosion resistance is one that is needed to be solved urgently.

That is, a silicon-made ultra-small sized mass flow rate sensor employs silicon as a constituent component to form gas contacting faces. Therefore, a fundamental difficulty is that it can be easily corroded by fluids of the halogen family and the like.

[0006] Furthermore, organic materials such as an epoxy resin, an O-ring and the like are used as sealing materials for the mass flow rate sensor, thus making the emission of particles or the occurrence of the outside leak unavoidable. Accordingly, it becomes unable that the sensor is applied for the gas supply line and the like in semiconductor manufacturing facilities.

[0007] Furthermore, there exists another problem with the mass flow rate sensor, that is, fluctuation in detecting values of the mass flow rate sensor occurs when the pressure of the fluid to be measured changes, or the distortion of the sensor itself caused by the mechanical tightening force (or thrust) occurs when a mass flow rate sensor is fitted to the gas supply line, which will be the cause of unevenness in the detecting values of the mass flow rate sensor.

[0008] Various techniques have been developed so far to solve difficulties

with the afore-mentioned silicon-made ultra-small sized thermal type mass flow rate sensor.

For example, with the TOKU-KAI No. 2001-141540 and the TOKU-KAI No. 2001-141541 and the like, there is provided a temperature resistance layer E_6 on the outermost layer of a film E formed on the upper face of he frame D made from a silicon substrate A as shown in Figure 20, to enhance stability of the film E. With Figure 20, $E_1 \sim E_3$ designate a silicon oxide layer to form a film

E, E_4 a silicon nitride layer, E_5 a platinum layer, and C a lead connecting hardware.

[0009] As stated above, with the afore-mentioned silicon-made ultra-small sized thermal type mass flow rate sensor as shown in Figure 20, there is formed a silicon nitride layer E_4 on the lower face side of the frame D, or a temperature resistant layer E_6 consisted of a silicon nitride layer, to enhance the water resistance and moisture resistance of the film E.

[0010] Patent Document 1: TOKU-KAI No.2001-141540 Public Bulletin

Patent Document 2: TOKU-KAI No.2001-141541 Public Bulletin

Disclosure of the Invention

Object of the Invention

[0011] The present invention is to solve the afore-mentioned problems with the conventional mass flow rate sensor such as (1) one that unevenness in property among products is caused and the response speed becomes low with a capillary thermal type mass flow rate sensor, and (2) the other that the emission of particles, the occurrence of outside leaks and the like cannot be avoided with a silicon-made ultra-small sized thermal type mass flow rate sensor in addition that it is less corrosion-resistant, and also that unevenness in detecting values of the mass flow rate occurs due to changes in the pressure of the fluid to be measured or changes in the fitting mechanism of the sensor. It is a primary object of the present invention to provide a corrosion-resistant metal made sensor for fluid and a fluid supply device for which the sensor is employed, (a) to make it possible that ultra-small sized products with the uniform quality is manufactured

by using micro-machine technologies, (b) further to make it possible that unevenness caused by changes in the detecting values of the fluid pressure is automatically adjusted, (c) to make it equipped with excellent corrosion resistance, (d) to make it possible that it achieves the high response speed and to make it particle-free, (e) to make it outside-leakless, and (f) make It possible that both mass flow rate and fluid pressure are detected.

Means to Solve the Object

[0012] Inventors of the present invention have come to an idea that by employing micro-machine technologies to form 2 resistance thermometer sensors, a heater, a lead wire to connect elements and the like required for a mass flow rate sensor part and a strain sensor element, a lead wire and the like required for a pressure sensor part by using a thin film body on the substrate made of corrosion-resistant metal such as stainless steel and the like so that (a) unevenness in quality of the sensor for fluid is prevented and corrosion resistance and responsivity are enhanced, (b) being particle-free and outside leakless are achieved, (c) unevenness caused by changes in the detecting values of the fluid pressure is automatically adjusted, and (d) the fluid pressure can be monitored through the pressure sensor part, and a prototype of a sensor for fluid equipped with the mass flow rate sensor part and the pressure sensor part has been built and the operation tests have been repeated based on said idea.

[0013] The present invention has been created based on the afore-mentioned idea and the results on various tests. The present invention as claimed in

Claim 1 is characterized by that it is so constituted that the mass flow rate and pressure of fluid are measured by its being equipped with a mass flow rate sensor part 3 comprising a corrosion-resistant substrate 2 and a thin film forming a temperature sensor 3a and a heater 3b installed on the back face side of the fluid contacting surface of said corrosion-resistant substrate 2 , and a pressure sensor part 4 comprising a thin film forming a strain sensor element 4a mounted on the back face side of the fluid contacting surface of the metal substrate 2.

[0014] The present invention as claimed in Claim 2 according to the invention

as claimed in Claim 1 is so constituted that a corrosion-resistant metal substrate 2 is fitted into the mounting groove 10a of a corrosion-resistant metal made sensor base 10 in a state in which its fluid contacting surface is exposed outwardly, and the peripheral edge of the corrosion-resistant metal substrate 2 is hermetically welded to the sensor base 10.

[0015] The present invention as claimed in Claim 3 according to the invention as claimed in Claim 1 or Claim 2 is so made that the output drift to the pressure of the mass flow rate sensor part 3 is corrected by the output of the pressure sensor part 4.

[0016] The present invention as claimed in Claim 4 is so made that a thin film F in Claim1, Claim 2 or Claim 3 is constituted with an insulating film 5 formed on the back side of the fluid contacting surface of the corrosion-resistant metal substrate 2, a metal film M which forms a temperature sensor 3a, a heater 3b and a strain sensor element 4a thereupon, and a protection film 6 to cover the insulating film 5 and the metal film M.

[0017] The present invention as claimed in Claim 5 is so made that a corrosion-resistant metal made sensor for fluid stipulated in one of Claims 1 to 4 is mounted on a fluid controller in order that the flow rate and pressure can be appropriately checked at the time of the fluid control.

[0018] The present invention as claimed in Claim in Claim 6 is so constituted that a sensor base 10 of the corrosion-resistant metal made sensor S for fluid stipulated in Claim 2 is positioned inside the fluid passage 21b of a body 21 equipped with the afore-mentioned fluid passage 21b for communicating between the flow-in inlet 21a for the fluid G and the flow-out outlet 21c for the fluid by installing a metal gasket 27 in order that hermeticity between the body 21 and the sensor base 10 is held by thrusting the metal gasket 27 through the mediation of the afore-mentioned sensor base 10, and at the same time stiffness of the structural component directly above the metal gasket 27 to hold the afore-mentioned hermeticity is relatively raised, thus suppressing the strain of the mass flow rate sensor part 3 and the pressure sensor part 4 caused by thrusting said metal gasket 27.

Effects of he Invention

[0019] In accordance with the present invention, a mass flow rate sensor is

manufactured by applying micro-machine technologies as in the case of the conventional silicon made ultra-small sized mass flow rate sensor, thus enabling to reduce unevenness in quality among products to a minimum. In addition, a corrosion-resistant metal substrate, for example, the substrate made with the SUS316L used for the sensor substrate is processed to make it a thin plate and

a resistance wire and the like are made to be thin films, to make the heat capacity of the sensor part extremely small, thus increasing the response speed of the sensor remarkably.

[0020] Also, in accordance with the present invention, all the gas contacting faces are constituted of a corrosion-resistant metal, and the sensor part and the sensor base are assembled by welding, and a metal gasket sealing is employed to mount them on a valve body and the like, thus enabling to achieve to make it corrosion-free, particle free and outside leak-free.

[0021] In addition, in accordance with the present invention, q mass flow rate sensor and a pressure sensor part are concurrently formed on the corrosion-resistant metal substrate, thus making it possible to adjust the amount of changes (the drift amount) of the mass flow rate due to changes of the fluid pressure by using the detecting values in the pressure sensor part, to allow accurate detection of the mass flow rate and also enable to output the detected values of the pressure to the outside when necessary.

Brief Description of the Drawings

[0022] Figure 1 is a plan schematic view of the sensor part of a corrosion-resistant metal made thermal type mass flow rate sensor according to the present invention.

Figure 2 is a cross-sectional schematic view taken line A-A of Figure 1.

Figure 3 is an explanatory drawing of the operating principle of a corrosion-resistant metal made thermal type mass flow rate sensor according to the present invention.

Figure 4 is explanatory drawings to illustrate the manufacturing process of a sensor part, where (a) is the preparation process of a stainless

steel thin plate, (b) is the formation process of an insulation film 5, (c) is the formation process of a Cr/Pt/Cr film (a metal film M), (d) is the formation process of a protection film 6, (e) is the formation process of an electrode insertion hole, (f) is the etching process of the back side of a stainless steel thin plate, and (g) is the separation etching process of a sensor part 1.

Figure 5 is a sectional schematic view to illustrate an example of a corrosion-resistant metal made sensor for fluid.

Figure 6 is a block diagram of a signal detecting circuit for detecting the mass flow rate of a sensor for fluid according to the present invention.

Figure 7 is a diagram to illustrate the relationship between the fluid pressure and the fluid sensor output/the bridge circuit output of the temperature sensor.

Figure 8 is a diagram to illustrate various characteristics of a sensor part according to the present invention, where (a) shows the relationship between the temperature of a heater and the resistance value of the temperature detecting resistance, (b) shows the relationship between the current of a heater and the resistance value of the temperature detecting resistance, and (c) shows the relationship between the gas flow rate and the sensor output.

Figure 9 is a diagram to illustrate the flow rate characteristics of a sensor when the compensation is performed against the pressure changes by using a pressure sensor part 4.

Figure 10 is a diagram to illustrate one example of a flow rate response characteristics of a sensor for fluid with regard to the present invention.

Figure 11 is a flow block diagram of a measuring circuit used for measuring the flow rate characteristics of a sensor S for fluid with regard to the present invention.

Figure 12 is a flow block diagram of a measuring circuit used for measuring the flow rate characteristics to the supply pressure changes of a sensor S for fluid with regard to the present invention.

Figure 13 illustrates the flow rate characteristics at the time of the supply pressure changes of a sensor S for fluid according to the present invention measured with the measuring circuit in Figure 12.

Figure 14 is a cross-sectional view to illustrate an example of the assembly drawing of a sensor for fluid according to the present invention.

Figure 15 is a cross-sectional view to illustrate the other example of the assembly drawing of a sensor for fluid according to the present invention.

Figure 16 is a cross-sectional view to illustrate another example of the assembly drawing of a sensor for fluid according to the present invention.

Figure 17 is a plan view to illustrate the other example of the assembly of a sensor for fluid according to the present invention.

Figure 18 is a cross-sectional view taken line B-B of Figure 17.

Figure 19 is a side view of Figure 17.

Figure 20 is a cross-sectional view to illustrate the outline of the conventional silicon made ultra-small sized thermal type mass flow rate sensor.

List of Reference Characters and Numerals

[0023] S Corrosion-resistant metal made sensor for fluid

F Thin film

M_1 Metal film which forms a mass flow rate sensor part

M_2 Metal film which forms a pressure sensor part

W Corrosion-resistant metal material

G Gas to be measured

1 Sensor part

2 Corrosion-resistant metal substrate

3 Mass flow rate sensor part

3a Temperature sensor

$3a_1$, $3a_2$ Temperature detecting resistances

3b Heater

4 Pressure sensor part

4a Strain sensor element

5 Insulation film

6 Protection film

6a Protection film for the mass flow rate sensor part

6b Protection film for the strain sensor part

7 Electrode insertion hole

9a · 9b Resists

10 Sensor base

10a Mounting groove

11 Heater driving circuit

12a Pressure offset adjustment circuit

12b Mass flow rate offset adjustment circuit

13 Offset adjustment circuit (for fine tuning)

14 Gain adjustment circuit

15a,15b Differential amplifying circuits

16 Mass flow rate output terminal

17 Fluid pressure output terminal

$4a_1$ · $4a_2$ Strain sensor elements

18 Signal treatment circuit

19 Multiplying treatment circuit

20 Joint part

21 Body

22 Sensor base presser

23 Wiring substrate presser

24 Wiring substrate

25 · 26 Guide pins

27 Metal gasket

28 Rubber sheet

29 Lead pin

30 Lead wire (a gold wire)

31 Body

32 Pressure detector

33 Control Valve

34 Piezo-electric valve driving device

35 Orifice

36 Filter

37 Relay substrate

38 Bearing

39 Fixture screw hole
40 He gas source
41 Pressure adjuster
42 Pressure type flow rate controller
43 Diaphragm vacuum pump
44 Driving circuit for the sensor S for fluid
45 Oscilloscope
46 Signal transmitter
47 3-way switching valve
48 Mass flow meter
$P_1 \cdot P_2$ Pressure gages
49 Secondary side pipe passage of the pressure type flow rate controller (inner capacity of 15cc or 50cc)
50 Pressure adjusting valve
S_0 Flow rate output of the sensor S for fluid
F_0 Flow rate output of the pressure type flow rate controller
M_0 Flow rate output of the mass flow meter

PT Output of the secondary side pressure gage
51 Fluid flow-in inlet
52 Fluid flow-out outlet

Best Mode of Carrying Out the Invention

[0024] [Preferred Embodiment 1 of the Corrosion-Resistant Metal Made Sensor for Fluid]

The embodiment in accordance with the present invention is described hereunder with reference to the drawings.

Figure 1 is a plan schematic view of the sensor part 1 which is an essential part of a corrosion-resistant metal made thermal type mass flow rate sensor according to the present invention. Figure 2 is a cross-sectional schematic view taken on line A-A of Figure 1.

[0025] Said sensor part 1 comprises a thin corrosion-resistant metal substrate 2, an insulation film 5 formed on the upper face of the substrate2, a mass flow rate sensor part 3 and a pressure sensor part 4 formed on the upper face of the insulation film 5, and a protection film 6 and the like formed

on the mass flow rate sensor part 3, the pressure sensor part 4 and the like.

Also, the afore-mentioned mass flow rate sensor part 3 comprises a temperature sensor 3a, a heater 3b and the like, and the afore-mentioned pressure sensor part 4 comprises a strain sensor element 4a and the like respectively.

Furthermore, a thin film F is formed with a metal film M which forms an insulation film 5, temperature detecting resistances $3a_1$, $3a_2$ of the temperature

sensor 3a, a heater 3b, an electric conductive lead part (not illustrated), a strain sensor element 4a and the like, and a protection film 6 on the upper face side (or on the back face side of the fluid contacting surface) of the corrosion-resistant metal substrate. And, an electrode insertion hole 7 with an approximate size is formed on the afore-mentioned protection film 6 by the etching process.

[0026] A gas G to be measured flows in the direction of the arrow in Figure 2 along the corrosion-resistant metal substrate 2 on the under face side (or the surface side of the fluid contacting surface) of the sensor part 1 as shown in Figure 2 and Figure 3. When this happens, some of the heat quantity contained with the gas G is given to the corrosion-resistant metal substrate 2, thus resulting in that the temperature distribution Tt of the corrosion-resistant metal substrate 2 shifts from the temperature distribution To where there is no flow of the gas G to the temperature distribution Tt as shown in Figure 3.

[0027] As stated above, changes in the temperature distribution of a corrosion-resistant metal substrate 2 caused by the flow of the gas G are presented as changes in the voltage values at the both ends of the temperature detecting resistances $3a_1$, $3a_2$ through the mediation of changes in the resistance values of the temperature detecting resistances $3a_1$, $3a_2$ which form the temperature sensor 3. Thus, the mass flow rate of the gas G can be known by detecting the changes in the voltage values as a differential output.

The above stated operating principle of the thermal type mass flow rate sensor is identical with that of the publicly known silicon made thermal type mass flow rate sensor. Therefore, the explanation in detail is omitted

herewith.

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[0028] Similarly, the pressure of the gas G to be measured is continuously detected through the mediation of the output of the strain sensor element 4a, and the pressure changes of the gas G are detected as the output changes of the strain sensor element 4a.

As described later, since the output of the mass flow rate sensor part 3 changes roughly in proportion to the pressure of the gas G to be measured, the detection value of the detected mass flow rate at the mass flow rate sensor part 3 is corrected by using the detected pressure value at said pressure sensor part 4.

[0029] The response speed and sensor sensitivity of the mass flow rate sensor part 3 are affected by the corrosion-resistant metal material W which forms the afore-mentioned sensor part 1 because the thermal capacity of the sensor part 1 is changed with its thickness. Referring to Figure 1 and Figure 2, with the present embodiment, a stainless steel thin plate (SUS316L) of less than 150 μ m thick is used. It is possible that the response speed and sensor sensitivity are raised by making the thickness less than 150 μ m, thus the heat capacity of the sensor part 1 being smaller. However, there is no need to say that the thickness could be more than 150 μ m if the sufficient response speed and sensor sensitivity are assured.

[0030] As described later, the afore-mentioned insulation film 5 is an oxidized film with thickness of 1.2 μ m~1.8 μ m formed by the so-called CVD method. With the present embodiment, a 1.5 μ m thick SiO_2 formed by the CVD (Chemical Vapor Deposition) method has been used for thee insulation film 5.

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[0031] The afore-mentioned temperature detecting resistances $3a_1$, $3a_2$ and heater 3b are made from a metal film M_1 formed by using the mask pattern (not illustrated) for the mass flow rate sensor on the afore-mentioned insulation film 5. With the present embodiment, the temperature detecting resistances $3a_1$, $3a_2$, heater 3b and the like are made from a metal film formed by Cr/Pt/Cr film (with thickness of 10/100/10 μ m respectively) being laminated in order by the vapor deposition method.

[0032] Similarly, a strain sensor element 4a is mad from a metal film M_2 formed by using the mask patter (not illustrated) for the strain sensor part on the afore-mentioned insulation film 5. With the present embodiment, the strain sensor element 4a and the like are made from a metal film M_2 formed by Cr/Cr-Ni/Cr film (with thickness of 10/100/10 μ m respectively) being laminated in order by the vapor deposition method.

[0033] The afore-mentioned protection film 6 is a film body to cover the upper part of the temperature detecting resistances $3a_1$,$3a_2$, the heater 3b, the strain sensor element 4a and the like. With the present embodiment, the 0.4 ~0.7 μ m thick SiO_2 film (the mass flow rate sensor part 3 and the pressure sensor part 4) formed by the CVD method has been used.

Also, said protection film 6 is provided with a suitably shaped electrode insertion hole 7 made by the plasma etching method, to draw out an electrode rod and the like through said electrode insertion hole 7.

[0034] The back face side of a corrosion-resistant metal substrate 2 which forms a sensor part 1 is finished with thickness of less than 150 μ m.

The sensor part 1 is eventually separated from the corrosion-resistant metal material W by the method of the so-called through-etching processing. As described later, the separately formed sensor part 1 is hermetically fixed to the corrosion-resistant metal made flow rate sensor base 10 by the laser welding or the like so that the corrosion-resistant metal made sensor S for fluid according to the present invention with the structure as shown in Figure 5 is constituted. Here, 10a is a mounting groove provided on the sensor base 10.

[Work Process of the Sensor Part]

[0035] Next, the manufacturing work process of the mass flow rate sensor part 3 which forms the afore-mentioned sensor part 1 is explained hereunder.

Figure 4 is explanatory drawings to show the manufacturing process of the mass flow rate sensor part 3 and pressure sensor part 4 which form the sensor part 1 with the present invention.

[0036] First, a stainless steel made thin plate (SUS316L) with appropriate dimensions, for example, of the diameter of 70~150mm ϕ and the thickness

of less than 150 μm is prepared for the corrosion-resistant metal material. (Figure 4(a)) There is no need to say that a thin metal plate (for example,, an austenitic steel plate made of a Cr-Ni alloy) other than a thin stainless steel plate can be employed for the corrosion-resistant metal material W.

[0037] Then, a SiO_2 film 5 (an insulation film) with thickness of approximately 1.5 μm is formed on the outer back face of the afore-mentioned prepared stainless steel thin plate by a plasma CVD device (Plasma-Enhanced Chemical Vapor Deposition Device) for which the TEOS (Tetrra-Ethoxy-Silane) is used.

(Figure 4(b))

[0038] After that, there are formed patterns of temperature detecting resistances $3a_1$,$3a_2$, a heater 3b and the like made from a metal film M_1 formed by the Cr/Pt/Cr film (with thickness of 10/100/10 μm respectively) by employing an electronic beam heating type vapor deposition device and a photo-mask patterns (not illustrated) for forming a mass flow rate sensor part on the afore-mentioned SiO_2 film 5. (Figure 4(c))

[0039] After a metal film M_1, which forms the afore-mentioned mass flow rate sensor part 3, having been formed, patterns of a strain sensor element 4a and the like made from the Cr/Cr-Ni alloy/Cr film (with thickness of 10/100/10 μm respectively) are made on the SiO_2 film 5 with a metal film M_2 by using the photo-mask patterns (not illustrated) for forming the pressure sensor part instead of the photo-mask patterns for forming the mass flow rate sensor part. (Figure 4(d))

[0040] And then, a SiO_2 film (a protection film) 6 of thickness of approximately 0.5 μm is formed on the temperature detecting resistances $3a_1$, $3a_2$ and heater 3b which form the mass flow rate sensor part 3 and the strain sensor element 4a which forms the pressure sensor part 4 made through the processes of the afore-mentioned Figure 4(c) and Figure4(d) with the plasma CVD device for which the afore-mentioned TEOS is employed. (Figure 4(e))

[0041] Then, on the afore-mentioned protection film 6, there are made an electrode takeout hole (an electrode insertion hole 7) with a bore of 200 μm

to be used for the temperature detecting resistances $3a_1$, $3a_2$ and a heater 3b, and

also an electrode takeout hole (not illustrated) with a bore of approximately 100 μ m to be used for the strain sensor element 4a by using the photo-mask patterns (not illustrated) to make an electrode insertion hole with the plasma etching device for which the CF_4 gas is used. (Figure 4(f))

[0042] Due to the reason that the SUS316L or Cr has a high tolerance to the plasma by the CF_4 gas, etching in progress stops automatically upon etching of the SiO_2 film 6 being completed. Accordingly, there is no danger of the so-called over-etching being caused at all.

[0043] Lastly, after resists 9a, 9b being coated, a sensor part 1 is detached from the material W by cutting through in a circular shape with the etching treatment using the ferric chloride solution ($FeCl_3$ · 40wt%).

[0044] The circular shaped sensor part 1 separated from the material W is fitted into the mounting groove 10a of the sensor base 10 formed in the shape as shown in Figure 5, and welded and fixed hermetically to the sensor base 10 by the outer periphery part being laser-welded. Thus, a corrosion-resistant metal made sensor S for fluid according to the present invention is constituted.

[0045] Figure 6 is a block diagram of a signal detecting circuit for detecting a mass flow rate of the sensor S for fluid according to the present invention. Said signal detecting circuit comprises a sensor part 1 formed by a mass flow rate sensor part 3 and a pressure sensor part 4, a heater driving circuit 11, a pressure offset adjustment circuit 12a, a mass flow rate offset adjustment circuit 12b, an offset adjustment circuit (for fine tuning) 13, a gain adjustment circuit 14, differential amplifying circuits 15a, 15b, a mass flow rate output terminal 16, a

fluid pressure output terminal 17, a signal treatment circuit 18, a multiplying treatment circuit 19 and the like. With Figure 6, $3a_1$ and $3a_2$ are temperature sensor elements, and $4a_1$ and $4a_2$ are strain sensor elements.

[0046] Referring to Figure 6, a mass flow rate sensor part 3 is heated by the operation of a heater driving circuit 11. When resistance values change with

the temperature changes of the upstream side temperature detecting resistance $3a_1$ and the downstream side temperature detecting resistance $3a_2$ which form the temperature sensor element 3a of the mass flow rate sensor part 3 while the gas G to be measured passes through, the changes are inputted to the differential amplifying circuit 15b as the changes of voltage, and the differential amplifying output is outputted to the mass flow rate output terminal 16 through the mediation of the mass flow rate offset adjustment circuit12b, the offset adjustment circuit 13 and the multiplying treatment circuit 19.

[0047] Due to the reason that the corrosion-resistant metal substrate 2 which forms a sensor part 1 of the present invention is made to be a thin film, the sensor part 1 strains with the gas pressure while the gas G passes through, thus resulting in changes of resistance values of temperature detecting resistances $3a_1$, $3a_2$ of the temperature sensor 3a, to make the bridge output of the temperature sensor 3a changed.

[0048] Figure 7 shows the relationship between the fluid pressure when there is made no adjustment with the pressure sensor part 4 (namely, the gain adjustment with the pressure offset adjustment circuit 12a, the adjustment with the offset adjustment circuit 13 by the output from the signal treatment circuit 18

and the gain adjustment with the gain adjustment circuit 14), and the mass flow rate output (the output mV of the output terminal 16) with the sensor S for fluid according to the present invention. The curves A, B and C show the measured values (in case of a current value 5mA to the temperature detecting resistances $3a_1$, $3a_2$) with three samples.

[0049] In either case when a heater 3b is operated or the heater 3b is not operated, it has been confirmed with the experiment that the output of the sensor S changes with the changes of the fluid pressure, or even with the same heater operating current the amount of the change in the resistance values to the fluid pressure P of the upstream side temperature detecting resistance $3a_1$ and the downstream side temperature detecting resistance $3a_2$ differ.

[0050] As stated above, when an ordinary resistance bridge circuit is

employed, there occurs a problem that the output of the sensor part 1 changes with the generation of strain. However, with the signal detecting circuit according to the present invention, it is so constituted that the rate of amplification of voltage values outputted from the upstream side temperature detecting resistance $3a_1$ and the downstream side temperature detecting resistance $3a_2$ and the offset are fine-tuned through the mediation of the strain sensor elements $4a_1$, $4a_2$, the pressure offset adjustment circuit 12a, the signal treatment circuit 18 and the like with the output from the pressure sensor part 4, thus changes in the output voltage values of the temperature detecting resistances $3a_1$,$3a_2$ produced by the application of the fluid pressure P being cancelled by adjusting the afore-mentioned amplification rate and the offset.

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As a result, it has become possible that output changes of the sensor part 1 by the gas pressure is perfectly constrained, thus making it possible that the mass flow rate is accurately detected.

[0051] Figure 8 illustrates characteristics of a sensor S for fluid according to the present invention. Figure 8(a) shows the relationship between the temperature of a heater 3b and the resistance value, (b) the relationship between the current value of the heater 3b and the resistance value, and (c) the relationship between the gas flow rate (SCCM) and the detected output value (V) respectively.

[0052] The resistance value of the heater 3b of the temperature sensor 3a used to measure various characteristics in Figure 8 is approximately 2.4kΩ, and the resistance values of the temperature detecting resistances $3a_1$, $3a_2$ are 2.0kΩ (both having identical values). 10mA current was passed to the heater 3b, and 1.2mA current was passed to the temperature detecting resistances $3a_1$, $3a_2$. Also, the fluid pressure is kept at a specific value of 100kPaG.

[0053] Furthermore, the changes in the output value of the sensor part 1 was approximately 1.0V when the gas flow rate was made changed in the range of 0~100SCCM. (However, the output value was amplified 500 times with the OP amplifier.)

[0054] In addition, because the output value of the sensor part 1 depends on

the clearance (the height of the flow passage) between the flow rate sensor base 10 of the sensor S for fluid and the fluid passage shown in Figure14 as described .later, the range capable to measure a flow rate can be appropriately switched by adjusting the afore-mentioned height of the flow passage.

[0055] Figure 9 illustrates the relationship between the fluid flow rate and the sensor output at the time when the pressure sensor part 4 is operated and the adjustment is performed by the pressure sensor part 4 in the afore-shown Figure 6. With Figure 9, Curve A_1 shows the case when the pressure sensor part 4 is not operated with the fluid pressure of 100KPaG (namely, Curve C in the afore-shown Figure 8), Curve A_2 shows the case when the fluid pressure is raised to 150KPaG (namely, the pressure sensor part 4 not being operated, and other conditions for experiments same as those of Curve A_1), and Curve A_3 shows the case when the pressure sensor part 4 is operated with fluid pressure of 150KPaG (other conditions for experiments same as those of Curve A_1) respectively. With the sensor S for fluid according to the present invention, it has been confirmed that even when the fluid pressure changes from 100KPaG to 150KPaG, the changes in the flow rate-output characteristics are completely prevented by operating the pressure sensor part 4.

[0056] Figure 10 shows one example of the flow rate response characteristics of the sensor S for fluid, and also shows characteristics in case when the gas flow rate is set at 0~100SCCM.

With Figure 10, Curve SA is the flow rate response characteristics of the sensor S for fluid according to the present invention, and the lateral axis is graduated in 250msec. Curve SF illustrates the flow rate response characteristics under the same conditions as those of the mass flow rate sensor with the conventional pressure type flow rate controller.

Figure 11 is a flow block diagram of the measuring circuit used for

measuring the relationship (Figure 9) between the gas flow rate (SCCM) and the detected output value (V) of the afore-mentioned sensor S for fluid according to the present invention. He gas is supplied from the He gas

source 40 to the pressure type flow rate controller 42 through the pressure adjuster 41, and the exhausted flow rate is measured with the pressure type flow rate controller 42 while it is exhausted by the diaphragm vacuum pump 43.

[0058] The sensor S for fluid according to the present invention, which is a sensor to be measured, is fitted to the primary side flow passage of the pressure type flow rate controller 42.

With Figure 11, 44 designates a driving circuit for the sensor S for fluid (a flow rate sensor), 45 an oscilloscope, and 46 a signal transmitter, The flow rate output S_0 of the sensor S for fluid is inputted to the oscilloscope 45, and is put in a contrast with the flow rate measurement value F_0 by the pressure type flow rate controller 42.

[0059] Figure 12 is a flow block diagram of the measuring circuit when the supply pressure of the afore-mentioned sensor S for fluid according to the present invention changes.

With Figure 12, 47 designates a 3-way switching valve, 48 a mass flow meter, 49 the secondary side pipe passage (with the inner capacity of 15cc or 50cc), 50 a pressure adjusting valve (the degree of opening so adjusted that P_2 becomes 100Torr at the He flow rate of 20SCCM), and P_1, P_2 pressure gages.

[0060] When the measurement is conducted, the pressure of the He gas supplied to the mass flow meter 48, the sensor S for fluid (a product of the

present invention · a sensor to be measured) and the pressure type flow rate controller 42 is made changed by opening/closing a 3-way switching valve 47.

The secondary pipe passage 49 of the pressure type flow rate controller 42 is so set that its inner capacity is 15cc (or 50cc). And, the secondary side Pressure P_2 is so adjusted by the pressure adjusting valve 50 that the pressure P_2 becomes 100Torr when the He gas flow rate is 20SCCM during the full load operation of the vacuum pump 43.

The detected flow rate S_0 of the sensor S for fluid, the detected flow rate M_0 of the mass flow meter 48, the detected flow rate F_0 of the pressure type flow rate controller 42 and the pressure measurement values P_1, P_2 are inputted and recorder respectively to the oscilloscope.

[0061] Figure 13 shows the measurement results obtained with the afore-mentioned measurement circuit in Figure 12. The state of changes in the detected values F_0, P_2, S_0, M_0 is shown at the time when the supply pressure is made changed from 200KPa · abs to 150KPa · abs. It is revealed that when the detected value S_0 of the flow rate of the sensor S for fluid according to the present invention is compared with the detected value M_0 of the flow rate of the mass flow meter 48, both detected values S_0 and M_0 of the flow rate (flow rate signals) keep up with the changes of the supply pressure

[Embodiment 1 of the Fluid Supplier]

[0062] Figure 14 shows one example of the fluid supplier equipped with a sensor S for fluid according to the present invention. It also shows a state of the sensor S for fluid being fitted to the joint part 20 mounted on the gas flow

passage. With Figure 14, 21 designates a body of the joint part 20, 22 a sensor base presser, 23 a wiring substrate presser, 24 a wiring substrate, 25 a guide pin, 26 a guide pin, 27 a metal gasket, 28 a rubber sheet, 29 a lead pin, and 30 a lead wire (a gold wire).

The afore-mentioned guide pins 25, 26 are used for positioning the mass flow rate sensor S when it is fitted to the inside of the body. Heremeticity between the sensor base 10 and the body 21 is maintained with the metal gasket 27.

[0063] While the fluid gas G flowed in from the fluid flow-in inlet 21a passes through a fluid passage 21b, its mass flow rate is detected with the sensor part 1, and the fluid gas G flows outside from the fluid flow-out outlet 21c.

With the present invention, there is no risk at all that the substrate 2 is corroded with the gas G as with the case of the conventional silicon made substrate because the gas to be measured passes through while contacting with the SUS316L made substrate 2.

[Embodiment 2]

[0064] Figure 15 shows the case that the sensor S for fluid according to the present invention is fitted to the main body part of the pressure type flow rate controller. With Figure 15, S designates a sensor for fluid, 31 a body, 32 a pressure detector, 33 a control valve, 34 a Piezo-electric valve driving device, 35 an orifice and 36 a filter.

[Embodiment 3]

[0065] Figure 16 shows the altered fitting position of the sensor S for fluid

according to the present invention. However, it is substantially same as that in Figure 15.

Since the constitutions of a pressure type flow rate controller and its main part have been disclosed by, for example, Patent No.3291161, the TOKU-KAI-HEI No.11-345027 and others, the explanation is omitted herewith. The method of fitting a sensor S for fluid is same as that in Figure 14. Therefore, the explanation is omitted herewith.

[Embodiment 4]

[0066] Figure 17 to Figure 19 show the other example in which a sensor S for fluid according to the present invention is fitted to a structural component which constitutes a fluid controller. Figure 17 is a plan view, Figure18 is a cross-sectional view, and Figure 19 is a side view.

With Figure 17 to Figure 19, 37 designates a relay substrate, 38 a bearing, 39 a fixture screw hole for the sensor S, 51 a fluid flow-in inlet, 52 a fluid flow-out outlet, The method of fitting a sensor S for fluid is same as those in Figure 14 and Figure 16. Therefore, the explanation is omitted herewith.

Feasibility of Industrial Use

[0067] The present invention is mainly used for detecting the mass flow rate and/or the pressure in the gas supply lines with semiconductor manufacturing facilities, various kinds of chemical product manufacturing equipment and the like. However, it can be also utilized for detecting the mass flow rate and pressure of a gas in the gas supply lines in many industrial fields.

Scope of Claim

What we claim is:

[1] A corrosion-resistant metal made sensor for fluid characterized by that it is so constituted that the mass flow rate and pressure of fluid are measured by its being equipped with a mass flow rate sensor part comprising a corrosion-resistant metal substrate, and a thin film forming a temperature